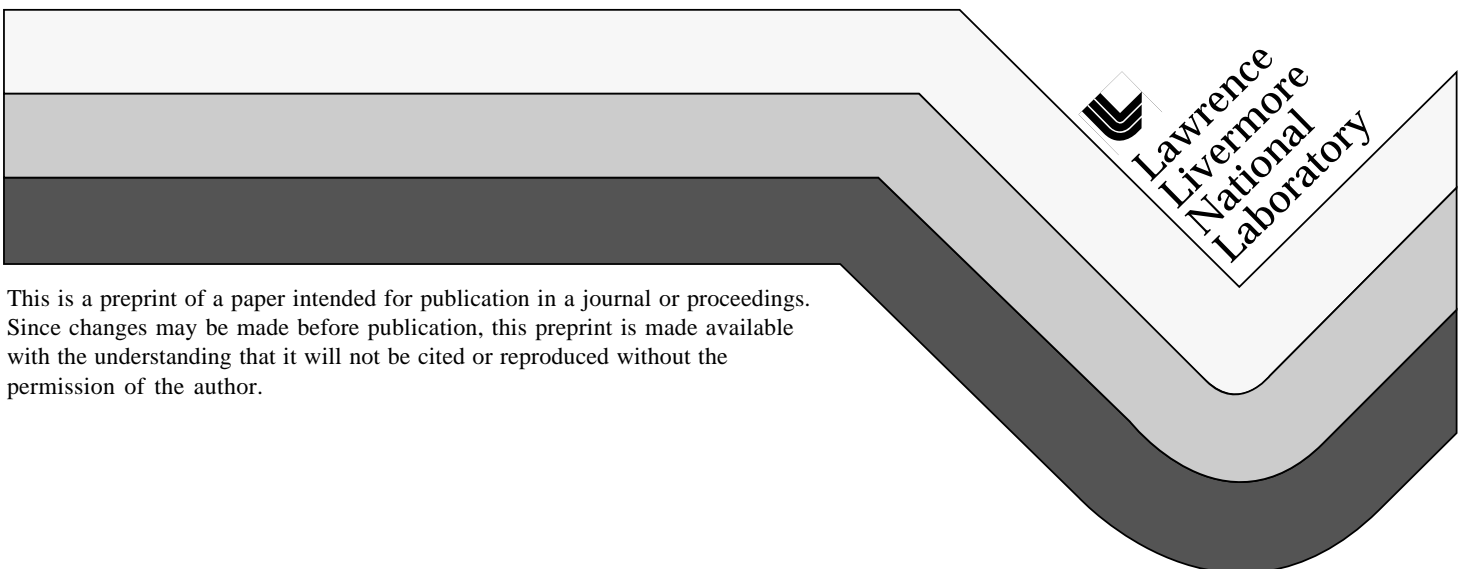


Geographical Information Systems: Thoughts Regarding Implementation and Transitions Between Steps

Fred J. Norton

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**Geographical Information Systems:
Thoughts Regarding Implementation and Transitions between Steps**

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June 10, 1996

This paper was prepared for the Energy Facility Contractors Group (EFCOG) CAD/CAE Facilities User Group Meeting, Marriott Irvine Hotel, Irvine, California, June 10–14, 1996.

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Geographical Information Systems: Thoughts Regarding Implementation and Transitions between Steps

Introduction

Approximately 539 organizations from around the world offer products and services that are related to Geographical Information Systems (GIS). The evolution of the annual GIS industry runs parallel to the development of the GIS in many organizations throughout the world.

The GIS field experienced tremendous growth in recent years in response to the expanding information needs of business and government and to technological advances such as faster, cheaper microcomputers, user-friendly desktop software, and low-cost and widely available spatial data. Dataquest, Inc., a computer-industry, market-research firm based in San Jose, California, estimates the 1993 GIS hardware and software market at \$1.8 billion, up 897% from \$177.2 million in 1987. These figures indicate the enormous magnitude of the GIS market without even including vital and growing components such as services (e.g., consulting and integration) or spatial data.

The latter part of this paper and my presentation will address the GIS implementation process. There are many ways to implement GIS within your organization. The transitions between the steps of a GIS implementation project are more difficult than the steps themselves. Yet these transitions are often underestimated or overlooked in the planning process and the management of the project. Transitions in the GIS implementation process must be anticipated, planned, and managed as carefully as the development activities.

In the survey results (Figures 1 through 10), please note that respondents were allowed to mark more than one answer; therefore, the percentages may add up to more than 100%.

Many new companies entered and flourished in the fledgling GIS business in the late 1980s and early 1990s (see Figure 1). On the other hand, some were not so lucky,

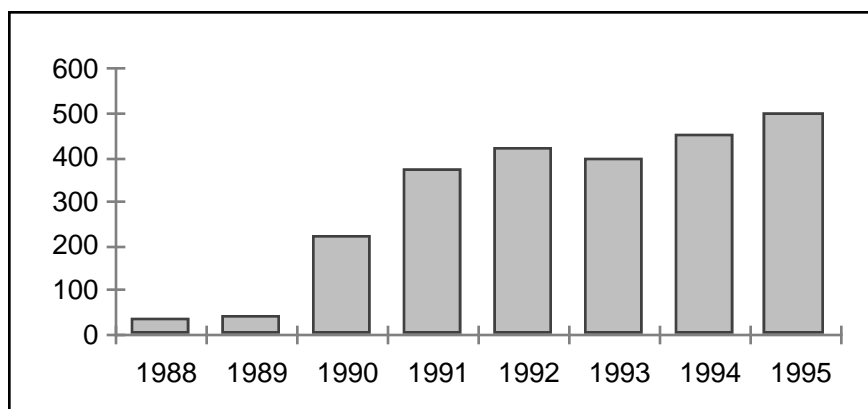


Figure 1. Annual responses to GIS world survey.

and survey results show considerable turnover in company names over the years. Regardless, the industry still is attractive for new entrants. Of the companies existing in 1995, 9% were founded in 1993 or later.

What is the GIS Industry?

Thousands of words and countless hours of debate and discussion have addressed the question, “What is GIS?” Perhaps now is the time to ask, “What is the GIS industry?” There is no doubt that for many years software developers comprised the core of what was considered the GIS industry. In fact, for some people, the term GIS was synonymous with GIS software. However, only three-quarters of the 539 companies provide GIS or related software (see Figure 2).

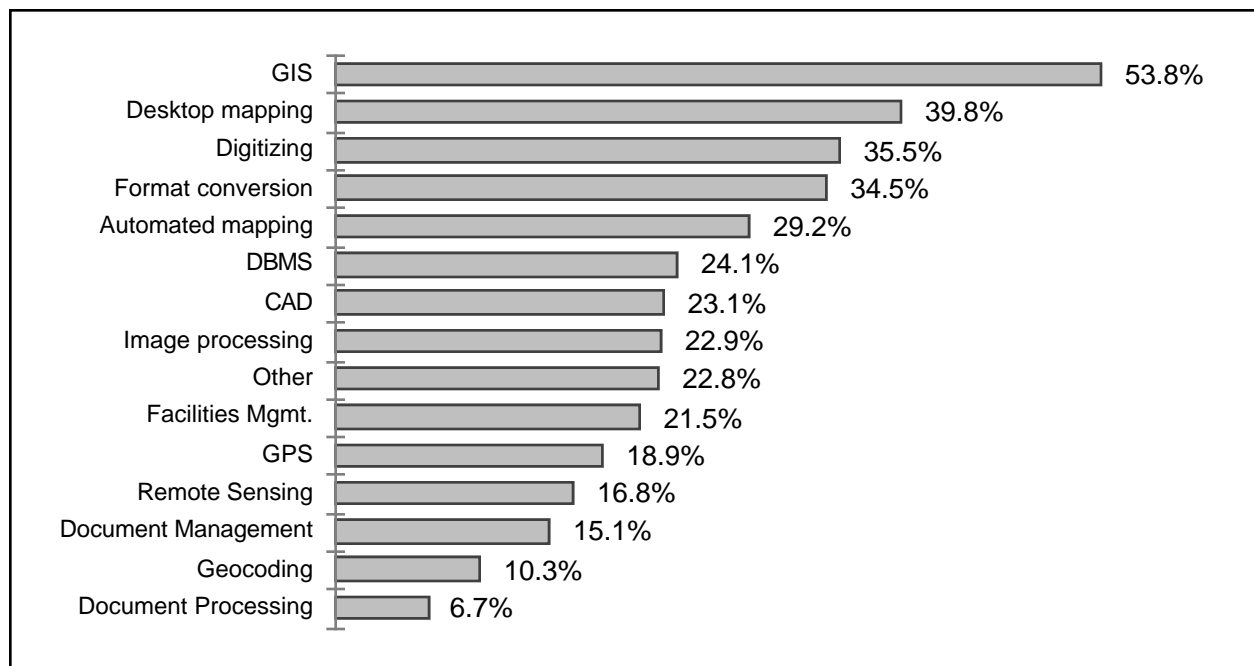


Figure 2. Software products provided by surveyed companies.

Services also have been considered an important aspect of the GIS industry, and they are vital to any organization contemplating the implementation of a GIS system. Many consultants and service bureaus provided data conversion, feasibility and cost/benefit studies, application development, pilot projects, and implementation assistance to early GIS adopters in government and utilities. GIS-related service providers still are involved in many of these activities. However, changes in how organizations use computer technology such as enterprise-wide information systems, plus the recent onslaught of client/server systems, have resulted in system integration's becoming an even more important part of the GIS service sector. About 94% of the 539 organizations looked at provide GIS services of some type (see Figure 3).

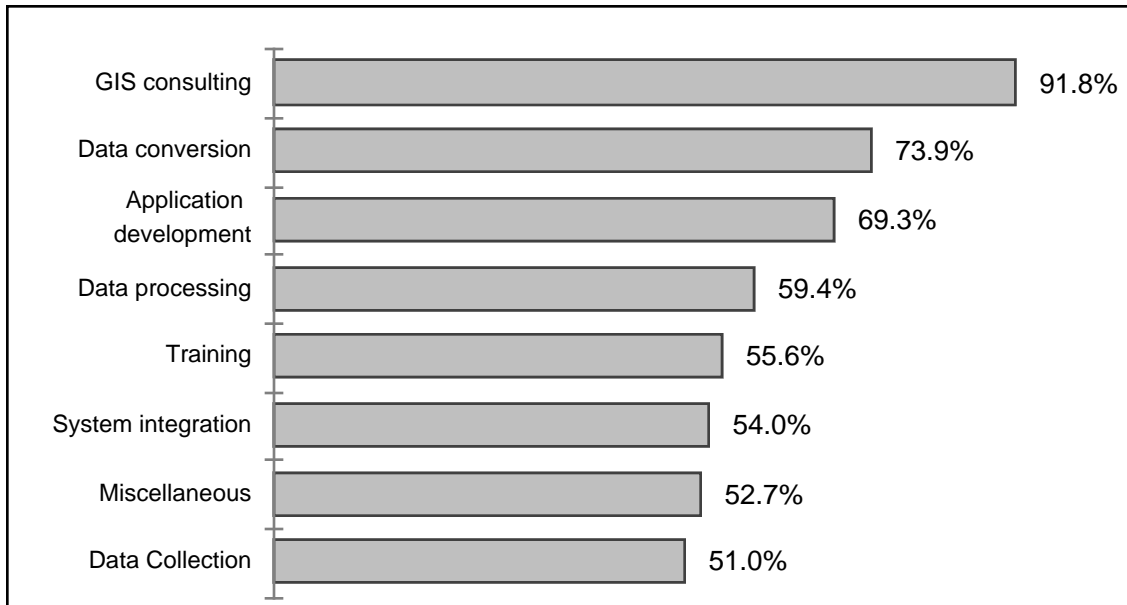


Figure 3. Services offered by surveyed companies.

Software and service companies are considered vital components of the GIS industry. However, as the industry evolves, organizations that produce, enhance and distribute spatial digital data likely will comprise one of the most valuable sectors of the GIS industry. Several factors will contribute to opportunities in the spatial digital data market in coming years. These include low-cost mass-distribution media such as CD-ROM, the Internet, and other on-line services, as well as a remarkable number of new data-collection sources.

Four U.S. companies have received licenses to launch and operate high-resolution, remote-sensing satellites in 1996 and 1997. In addition, RADARSAT, a Canadian company, launched its remote-sensing satellite in late 1995. Global positioning system (GPS) technology also has gained considerable acceptance among GIS users. Please note that 43% of the GIS users polled have implemented some form of GPS data collection.

The size and growth of the GIS software market and its user base no doubt have spurred the economic feasibility of a digital, spatial-data sector in the industry. Concurrently, about one-third of the companies in the survey provide off-the-shelf digital data (see Figure 4).

As timely, accessible, and reasonably priced digital, spatial databases become increasingly available to existing and potential GIS users, they are expected to drive strong growth in the software, hardware, and services sector by eliminating some of the GIS technology-adoption barriers erected by the high costs of creating databases.

The growth and development of the business-geographic market may provide a good model by which to predict the future of the overall GIS market. The market's staggering growth has been driven by improvements in computer hardware speed and cost and by the widespread adoption of PC-based graphical user interfaces (GUI). The technological developments fostered user-friendly, low-priced PC-based GIS and opened the market to potential users the same way PC-based AutoCAD brought affordability to the computer-aided-design market.

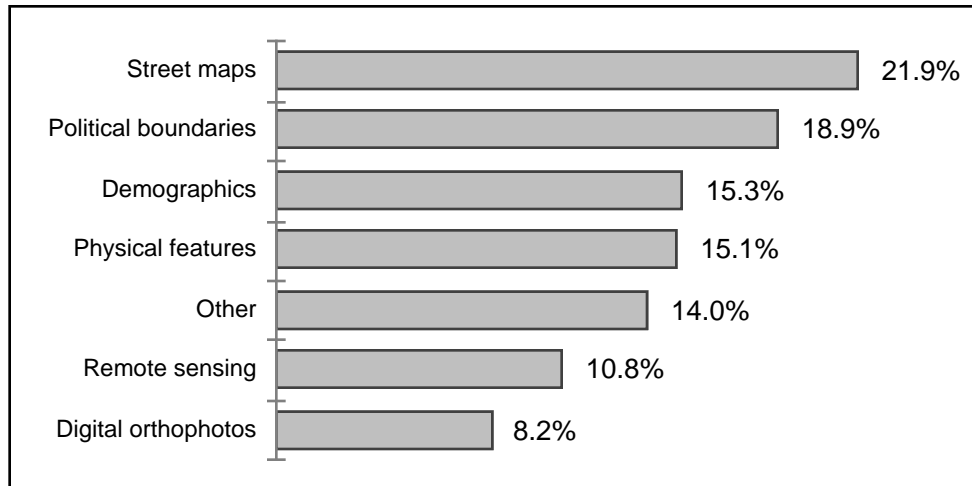


Figure 4. Data sets offered by surveyed companies.

However, even with the possibilities created by technology, the most critical growth driver for business geographics was the accessibility of digital, spatial databases. The release of TIGER files from the 1990 census on 44 CD-ROMs did more to enlarge the business-geographics industry than any single event by distributing digital, spatial data at a reasonable cost. Much of the data needed for business-geographics analysis, such as census demographics and census- and ZIP-code boundaries, are economically impossible for a single user to collect and digitize. At the same time, the potential user base for digital versions is enormous. Without access to digital, spatial databases, potential business geographers have no use for PC-based GIS, regardless of how fast and user-friendly it is. Affordable digital, spatial databases offer a compelling reason to purchase powerful, PC-based geographic software and drive the growth of the industry.

GIS Software

The GIS Software Survey is at the heart of this document. In the computer database that is being created, there are about 486 products from 278 companies that supply software. Almost half of these products are categorized as GIS software (see Figure 5).

Other key software categories include desktop mapping, automated mapping/facilities management, database management, and digitizing. Most software products are included in several categories, reflecting the variety of uses to which they are applied.

Operating Systems

Microsoft Windows and DOS are the dominant operating systems for software products included in the survey (see Figure 6). UNIX runs a close third; it operates about 44% of GIS and related software products. These data indicate the growing importance of PC-based geographical information technology (IT) and the relative decline of UNIX as the GIS operating system of necessity. However, operating system preferences vary considerably in different user organizations. Figure 7 shows that UNIX maintains a

strong following among many GIS users in traditional GIS markets such as government and utilities, while DOS and Windows are the most common operating systems in the business-geographics market.

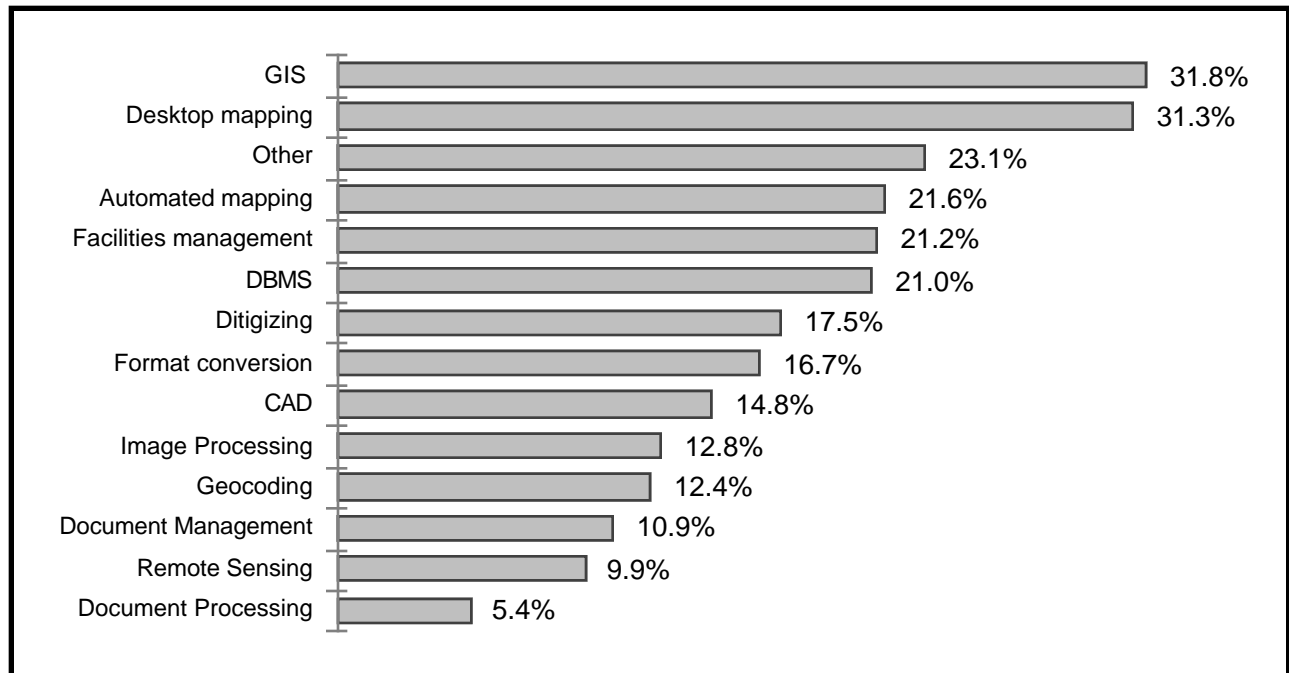


Figure 5. GIS software included in survey.

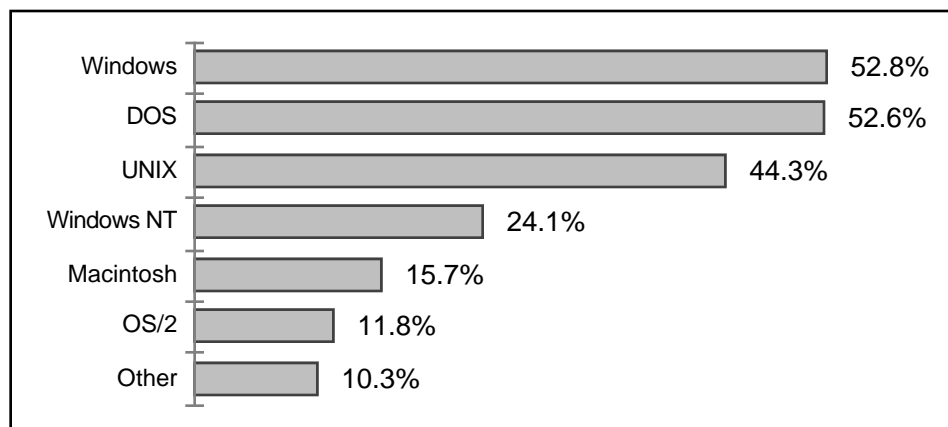


Figure 6. Operating systems supported by GIS software.

Database Interfaces

Oracle and dBASE are the most commonly supported external databases for software products included in the survey (see Figure 8) and also are favored by GIS users (see Figure 9). Internal databases are supported by more than one-third of the software products offered. As with operating systems, data from the survey show that differences in database use exist between business and traditional GIS users. Business users tend to

use PC-based software such as dBASE, Access, Fox Pro, and Paradox. Traditional market segments, such as governments and utilities, use the packages as well, but they also have a strong leaning toward UNIX-based packages such as Oracle and Informix.

Data Exchange Formats

ASCII is the most common file format supported by GIS and related software products, as is the case with most lines of computer software (see Figure 10). DXF, the AutoCAD file format, is the second most commonly supported format, reflecting AutoCAD's strong presence in the GIS market and its format as a *defacto* exchange format. The Spatial Data Transfer Standard (SDTS), the federal Geographic Data

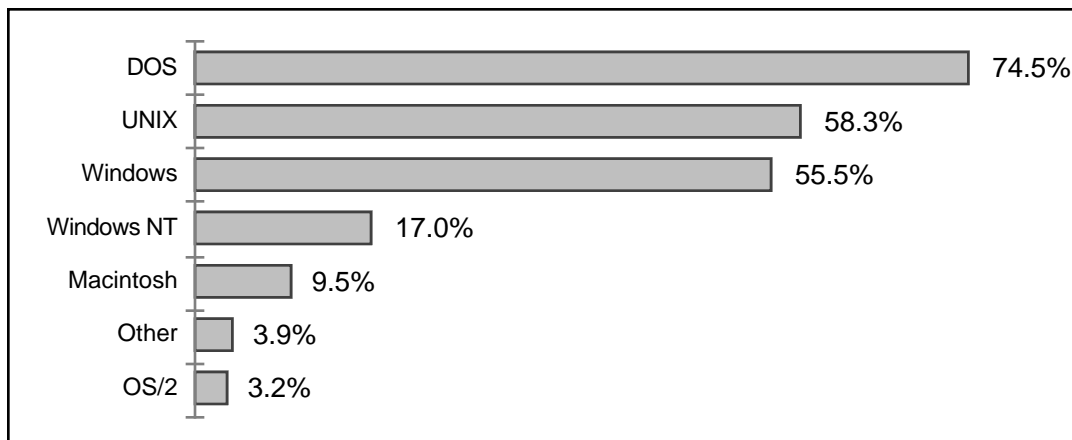


Figure 7. Operating systems preferred by GIS users.

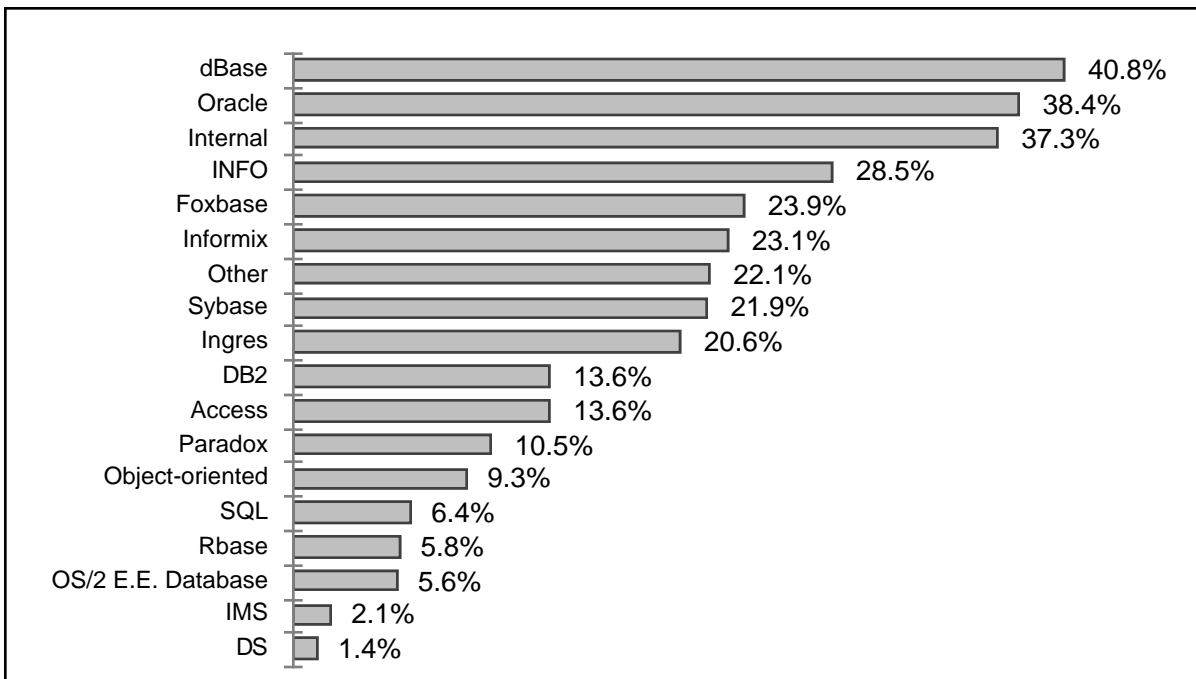


Figure 8. Databases supported by GIS software.

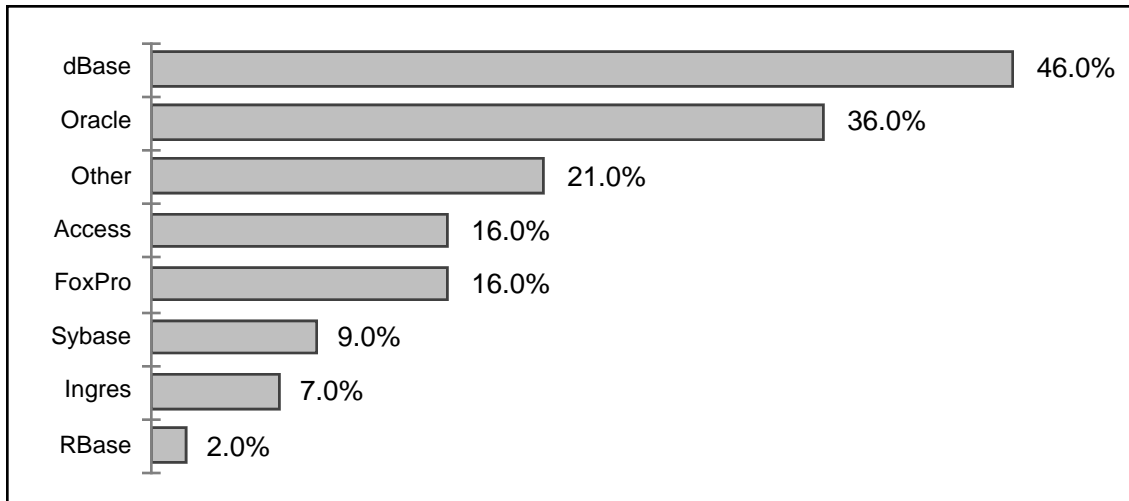


Figure 9. Databases preferred by GIS users.

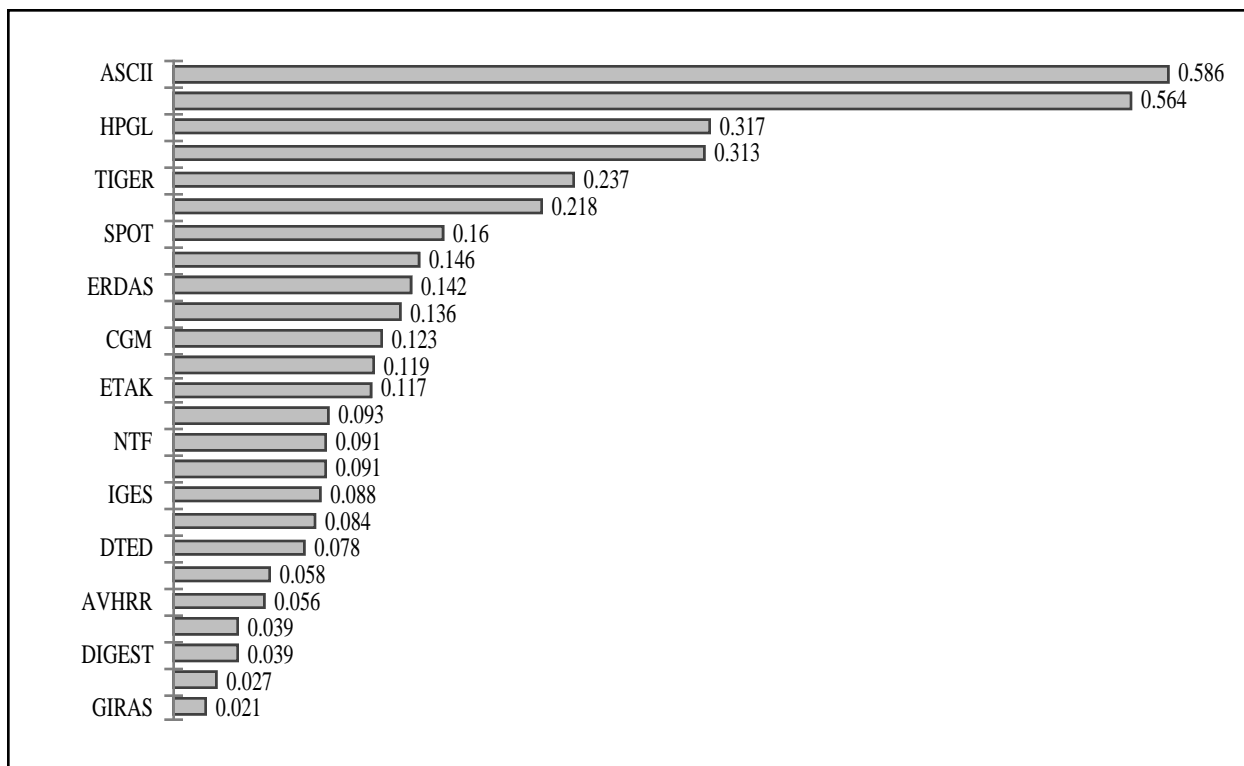


Figure 10. File exchange formats supported by GIS software.

Committee (FGDC), is supported by less than 4% of the GIS products included in the survey. However, these products include such market leaders as ARC/INFO (import only), MGE, and GDS.

Prices

Software prices in the survey range from less than \$100 for electronic atlas-type programs and system add-ons to \$110,000 for SoftPlotter from Autometric, Inc. While the average reported price for GIS-related software was \$5,848, half the software packages in the survey were priced at \$2,495 or less, and only 25% were priced at more than \$5,000. These data indicate the availability of several very expensive GIS-related software packages.

Installed Base and Number of Users

Although the average installed base for GIS software packages is more than 5,000, half the software included in the survey has 50 or fewer installations, and 75% have 300 or less. Several packages boast extremely large installed bases, including AutoCAD, which claims one million installations. Similarly, while the average number of users per software package is slightly more than 7,800, half the software in the survey has 110 or fewer users.

The distribution of installations and users among software packages included in the survey is testimony to the heavy concentrations in the GIS software industry. Figures from Dataquest indicate that the two largest GIS software firms account for 34% of industry revenue, the top five account for more than 55%, and the top ten for more than 71%. There are still many small firms operating in the industry; with strong growth expected for the next few years, their futures are bright.

Small GIS companies play an important role in the industry, particularly in terms of software and technology innovation. Their major opportunities come either from developing new technology and being purchased, from partnering with large players, or from developing new products and going it alone to gain market acceptance. For example, Terralogics, Inc., which developed embedded-mapping technology, was purchased by Strategic Mapping, Inc., in a move that benefited both companies and the GIS industry by expanding the potential market for geographical technology through partnerships with companies like Lotus Development Corporation and Novell. Several small companies appear to be making a success out of going head-to-head against the big players with their own product lines. For example, Caliper Corporation and Scan/US appear to be competing well with their low-cost GIS products.

Implementation of GIS

This portion of the paper addresses the GIS implementation process. There are many ways to implement GIS within your organization. The implementation process discussed below reviews some basics for implementing such a system, especially for those who are new to GIS. This section of the paper provides a brief overview of the GIS implementation process and is intended to do the following:

- Provide basic information for GIS newcomers.
- Identify current issues in the implementation of GIS.
- Establish a framework and context for future GIS issues.
- Provide some sources for guidance on the implementation of GIS.

Implementation Issues

Although the basics of the GIS implementation process are fairly straightforward, the task can appear confusing. On the one hand, GIS is so prevalent that it seems as though it should be easy and inexpensive to just get a system and start using it. On the other hand, the task can seem so daunting and expensive that organizations delay it for too long. Neither approach is very effective. Although inexpensive GIS software, hardware, and data have become common, it is also true that the total, long-term costs of all components of any one GIS can be very high. GIS can be implemented for a few hundred or for several million dollars.

Implementing a cost-effective GIS for an organization is a straightforward process that is based on several key components. These include an understanding of the implementation process, knowledge about GIS technology, an appropriate level of GIS development expertise, willing participants, and an adequate budget. The guiding principle is that GIS is needs-based. While there may be a limited number of GIS software systems, each GIS that is implemented is unique to its own organizations. The most important factor in implementing GIS is a realistic understanding of data and operational needs.

Therefore, GIS implementation involves the following five basic phases:

- *Planning*. Planning includes establishing resources, activities, and schedules.
- *Analysis*. Analysis includes determining the organization's requirements.
- *Design*. Design helps determine what type of system will meet the organization's requirements.
- *Acquisition and Development*. This includes acquiring the software, hardware, and data, and crafting them into a personalized system.
- *Operation and Maintenance*. This includes using and keeping the system current.

During each phase, several activities must be addressed, and decisions made. These basic components are the same for most organizations, applications, and sizes of GIS. The extent to which they must be explored, the amount of time it takes, and the decisions reached, however, are unique for each situation. The implementation process could take a year or a week, depending on the size of the organization, the number of users and applications, the size of the database, and the size of the GIS. In any event, users must follow some form of this process.

Planning

Planning is the most important part of GIS implementation, regardless of system size. Many organizations try to take short cuts in the planning phase, because there are many factors that pressure them to do so. These include, but are not limited to, political and administrative pressure to show progress; pressure or directives to use certain software, hardware, or data; and lack of understanding of the GIS planning and implementation process. Recently, inexpensive software and data have resulted in added pressures; that is, managers may reason that if GIS software will only cost them a few thousand dollars, such a small investment does not warrant a lot of research and analysis.

In any event, many organizations do not devote adequate resources to planning systems beyond the software and hardware environment. The problem with this

approach, however, is that the system costs are just the tip of the iceberg. After acquiring the system, time must be spent on gathering data, developing applications, and training, not to mention organizational commitments.

The software and hardware may only amount to 20% of the GIS costs; time spent on planning the other 80% will be worthwhile in the long run.

The first step in planning a GIS implementation is establishing the basic function and scope of the system. Will it be used for all mapping in the organization? Will it only be used to support a single project? Will the GIS database serve as the central database for all land-related applications within the organization? Will it be used by everyone or only by a handful of people? Will you be part of a larger effort? These basic questions help establish the scope of the GIS.

Although the details may be unknown at this point, it must be determined whether the GIS will be limited to a single software package on an existing PC, or comprise a network of hundreds of users, dozens of databases, and a suite of GIS-related software products. Does the organization need full-function GIS software, desktop mapping, or a bridge between computer-aided design (CAD) and computer-aided engineering (CAE) and GIS? Will users connect or share data with other systems? Details concerning all these matters will be developed later, but these basic questions must be answered before proceeding. The answers will guide the efficient execution of the next step as well as provide basic budget guidance.

To answer the questions posed above, some GIS knowledge is necessary. Education is an important component of the GIS planning stage, and the people who will participate in the GIS development must acquire an appropriate level of knowledge before further analysis can be conducted. This may involve reading, attending seminars or classes, attending GIS conferences or trade shows, or conducting some in-house education. Different people have different backgrounds, will use the GIS differently, and will play different roles in GIS implementation. Therefore, education should be tailored to individuals.

The individuals who will be involved in using the GIS must be included early in the process to provide information for the requirements analysis that comes next. To participate in this process, they will need the appropriate level of education, as mentioned earlier.

Finally, the resources needed to proceed with GIS implementation must be identified and implemented. This may be as simple as scheduling time to devote to GIS, or it may involve assembling and managing a team of several members. It also includes identifying and planning for any necessary outside assistance and expertise.

Analysis

Users know what they want the GIS to do in general terms, but to analyze requirements, they must be much more specific. Several key areas must be examined and specified: applications and users, data, and organizational involvement. Each is discussed below.

Applications and Users

Identify the applications and work processes that use geographic data and maps. Usually, this is fairly obvious, particularly when considering GIS for certain operations. What is often less obvious is that many other operations use nongraphical forms of geographic data. Identifying these applications as well is a good idea because later they may need to be linked to the GIS.

Identify the data and maps the applications use and think about how these applications would be done if GIS functions were available. Don't get drawn into designing the details of the GIS yet; focus on how the application or the operation would work if GIS were a tool. Look at what data is required for input, what operations are performed, and what the output of the process is. When map production and access is the major function, this analysis can be fairly straightforward.

Other applications may not be as simple as they seem. In many instances, it helps to step back and look at the purpose of an application. GIS tools and data may have the potential to change the actual operation significantly. Analyzing the GIS requirements and planning to use GIS in the work often result in redesigned work processes (also known as reengineering). This goes beyond just automating your current processes, or switching them from CAD/CAE to GIS. The way the organization uses and produces data and maps is based on the technology available in the organization. The capability of new technology may create different ways to approach the task. Reengineering work processes often enables an organization to gain more advantage from the benefits of GIS.

Identify which users will be associated with which applications. Different users may perform very similar applications, such as map production or vehicle routing, and may also be involved in a variety of applications. The activities to be performed within applications will translate into GIS functions for which the appropriate GIS software tools must be found.

Data

Look at the operation from the viewpoint of the data. What data will be used? What are their characteristics, attributes, origins, and flows? How are the data constructed, manipulated, updated, stored, accessed, and represented? It is important to think about the answers to these questions as they apply today, as well as the way data should be handled in the future.

Important data items include not only the ones you need for your own operation, but also any base map data that may be needed. Issues of data sharing must also be considered at this time. Some of the important issues regarding data include, but are not limited to the following:

- *Appearance.* Standards for how data will be created and displayed.
- *Source.* Includes who is responsible for input and maintenance.
- *Format.* The physical format and technical specifications for source data.
- *Means of Input.* This depends on source, format, and available technology.
- *Resolution and Accuracy.* Depends on current and needed requirements.
- *Location.* The physical location of source, users, and input.
- *Currency.* This is the date of the initial data and update cycles.
- *Volume.* For each entity, how many?

- *Access.* Who will access which data, how much, how often, and where?
- *Cost.* This applies to the acquisition, collection, or conversion of data.

According to the Federal Geographic Data Committee (FGDC), metadata is the description of the content, quality, condition, and other characteristics of data. It is crucial, and it may include such factors as source, input date or last update, accuracy, and so forth. Metadata helps a person to locate and understand data. Metadata is important for facilitating the use of GIS.

Organizational Involvement

An organization's characteristics and the environment in which it operates are important factors in the implementation of GIS. Each organization has its own culture (i.e., culture represents conditions, constraints, and opportunities). One important factor is whether the organization is willing to change to accommodate or best benefit from GIS, such as required by the reengineered work process discussed previously. Another important issue is determining the appropriate scope for the GIS. For example, initial impressions may have been that GIS would benefit the entire organization, but the reality is that it can be implemented in limited places at the present time. It is important to be realistic about organizational constraints as well as to be able to recognize and act on opportunities when they occur.

The environment will also present conditions that must be met: clients, users, or other organizations may require data in certain formats or under certain conditions. Opportunities may also be present for sharing costs or finding new markets once the GIS technology is operating.

Although many more details need to be examined and analyzed, understanding the organization's GIS needs basically boils down to understanding the application(s) and data needs. A GIS is just data and functions supported by computer systems. During this analysis phase, remember to stick to detailing requirements, not the GIS itself.

Design

The design phase involves putting the components together, that is, determining how the software, database, applications, and users must work together to accomplish the operations and applications requirements. This phase provides the specifications for matching your application and data requirements to available GIS products and services, and it provides the blueprint for developing the system.

Levels of GIS Design

GIS design has three basic levels of detail:

- The first level is generally called the conceptual design. This consists of a very high-level model of the basic components of the system, that is, the data sets or layers, the functions, applications, and users. After becoming comfortable with the scope of the system, this information may be sufficient for initial acquisition of a very small or limited GIS.

- The second level, the detailed design, includes elaborating on the specifications for data and for software and hardware functionality. During this phase, specifications that are crucial for data acquisition or collection will be determined, applications described in detail, and functions specified. For most GIS efforts, at least some of this detail is required to make an appropriate purchase of software, hardware, and data. For organizations that are using a Request for Proposal (RFP), process, these specifications become the RFPs.
- The third and final level of detail in GIS design involves optimizing the database and applications design to run on the software of choice.

Design Components

The basic components of a GIS design are as follows:

- *Data.* Data include descriptions of the characteristics, relationships, structure, format, specifications, sources, maintenance schedules and responsibilities, volumes and locations, and metadata.
- *Applications.* In users' terms, applications describe the intended use of the system. Each application should include the data volume and frequency, the users and their locations, and any links to other applications and databases. Some applications may be available from vendors as specified, others may require application development.
- *Functionality.* The required functions can be inferred from the applications, but it is often a good idea to derive them directly and specify them, just to make sure nothing gets left out. The functions are the tools provided by software and hardware and are put together to form applications.
- *Performance.* Specify performance and response criteria in users' terms.
- *Cost-Benefit Analysis.* The details developed during the analysis and design activities provide the information needed to do a reliable cost-benefit analysis. The analysis may also include the benefits derived from cost sharing, increased market potential, and income from GIS products and services.
- *Technical Implementation Plan.* Develop activity, resource, responsibility, and schedule plans for implementing the software, hardware, data, applications development, communications, integration, and so forth. Everything involved in getting the system ready should be included.
- *Organizational Plan.* Plan everything involved in getting the people ready. This includes training, staffing, education, transition plans, and reorganization, if any.

All these components (steps) work together; therefore, all must be completed before you move on. If they fall out of synch, the problems will change.

Acquisition and Development

Because types of GISs vary widely, so do the processes for acquiring and developing them. A basic issue, however, is to sort out which components (steps) will be bought and which will be developed.

GIS software is a basic toolbox that provides input, editing, storage, management, access, viewing, plotting, analysis, and manipulation capabilities for geographic and map data. Most applications must be developed using these tools. Development can be done by the software vendor, an applications development vendor, the organization's project management team, the users themselves, or sometimes by a combination of these. Some organizations use RFP processes to obtain products and services. Others can make their decisions based on their criteria and vendor-supplied information. The important point in either case is that the products and services are evaluated with respect to the organization's criteria. That is the only valid way to make a comparison.

Database implementation also presents many options. For some organizations, data conversion is by far the biggest component of the system. Local governments, for example, typically contract for the planimetric and cadastral data conversion. Utilities often do the same for their landbase and facilities. For other types of organizations, GIS is acquired as a tool to handle the data they create or obtain in the course of their operations. In this case, there may be no "base map conversion," but converting data from their existing format to the new GIS format may be an issue. Other organizations, particularly those performing "business GIS" applications, buy much of the GIS data.

Even if data conversion is not a major part of the GIS implementation effort, developing procedures for data input is important. As with the acquisition of system components, data and data conversion services must be evaluated with respect to the design specifications. Because too much data exists to convert in one step, most GISs are implemented incrementally. This issue aside, the complexities of bringing in software and hardware, developing applications, training users, and switching over to GIS operation often require a phased approach.

Operations and Maintenance

A GIS is a computer system. As such, most of the guidelines for operating and maintaining computer systems apply to GIS. These include trouble shooting, vendor-support coordinations, system backups, configuration management, input and output control, and so forth. Because of its special characteristics, however, GIS involves some additional system operation and maintenance.

One important issue for GIS pertains to maintaining the database. Users will assume that what they see is current and correct. Procedures must be developed for updating according to established standards and cycles. Appropriate metadata must also be provided in order for the user to know the currentness, accuracy, and source of the data.

Another issue that arises in GIS operation is the appropriate access and use of the data. A GIS can contain many diverse sets or layers of map data that can be overlaid or used in combination. The system manager must institute guidelines to help users avoid mistakes or inappropriate use, e.g., combining data of differing dates or accuracy and computing them as if they were the same. Again, metadata is very useful in this regard. Data access issues present some of the most challenging aspects of running a GIS.

Multi-participant GIS

When a GIS is being developed for personal use, or for limited use within an organization, many of the steps and issues discussed previously may be simplified. They may be done quickly, and the answers may be simple and obvious. Make reasonable efforts, however, to consider any possible expansion; foresee future needs and environments and consider their impact on today's decisions.

Organizations often find that there are already many GIS activities in their areas with which they may want to coordinate. In some cases, operational systems may exist that set certain standards for data, or even for software in the area. Cooperative GIS projects try to develop standards that suit all involved while also providing opportunities to share costs. In these situations, the GIS implementation steps and issues described previously become more complicated. External players may need to be included in your system analysis and design plans—or the organization may find itself playing a role in a GIS project being led by someone else. When there are multiple participants developing coordinated GISs, all of their requirements must be taken into account during the analysis phase. Everyone's requirements must be included as part of the system; then, the system can be designed to include or integrate these other users. Compromises may be required, and their viability should become apparent in the cost-benefit analysis.

General Remarks

This portion of the paper and presentation has provided an overview of the activities and issues involved in implementing GIS. Some sources that provide more in-depth discussion of these process are mentioned in the annotated Bibliography appended to this paper. A variety of conferences, papers, articles, and other literature address aspects of the GIS implementation process and related issues. Evaluation and use of recommendations found in such sources must always be done with respect to the principles of the basic process and the particular organizational context.

Transitions in the GIS Development Process

The GIS implementation process is usually thought of as a series of steps, phases, or activities. The basic steps of the process are portrayed in Figure 11(a) and described as follows:

- Step 1, project initiation, involves establishing the vision and goals of the GIS, identifying the development and future GIS users, acquiring the necessary information and education for participants, and developing a preliminary implementation plan.
- Step 2, commonly referred to as the requirements analysis, involves working with the future users to determine their functional and data requirements and assessing resources, opportunities, and constraints in the organizational and institutional environment.

- Step 3, the design step, entails developing a conceptual design for the GIS, database, applications, and organizational aspects and testing them against the results of the requirements analysis.
- Step 4, the GIS acquisition and development phase, involves developing software, hardware, and data specifications for system selection and acquisition and data acquisition or conversion, and/or both. Implementation involves installing software, hardware, and the database, as well as performing the organizational development required to support and use of GIS.
- Step 5, the final step and the operations and maintenance phase, consists of integrating GIS into the organization's operating environment and managing the ongoing process of data and system maintenance.

The activities to be performed at each step are fairly straightforward. Each step has a number of substeps and related activities and there are feedback loops between steps. Different people represent the process somewhat differently, but the basic steps remain the same and are fairly well explained. Guidelines for the various tasks are abundant in GIS literature and meetings, and most organizations perform each step fairly well.

The harder part of successfully managing the GIS development process is making the transitions between the steps. These transitions are not so well explained, partly because the circumstances related to transitions vary more among organizations than do the steps themselves.

Figure 11(b) illustrates the transitions inherent in the portrayal of the simplified steps in Figure 11(a). The obvious transitions are between project initiation and requirements analysis, between requirements analysis and design, between development and implementation, and between implementation and operation. Considering these transitions between steps is as important as planning the steps themselves.

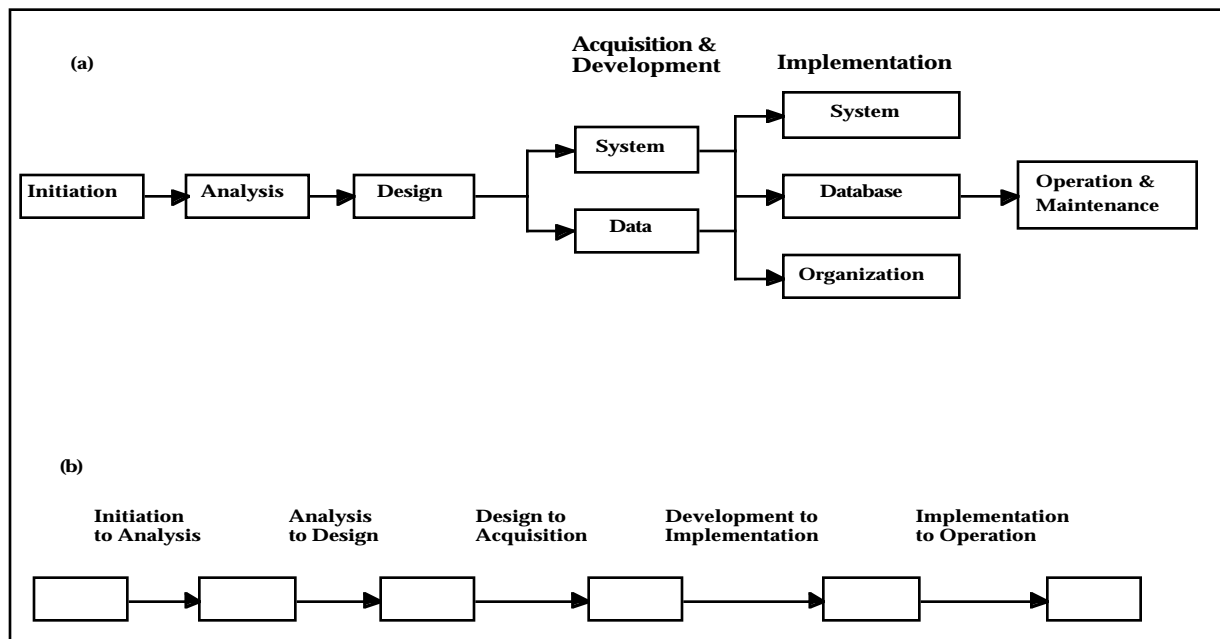


Figure 11. GIS implementation process: (a) the steps and (b) the transitions.

Overcoming Difficult Transitions

If you look at the situations in which GIS projects have problems, you will find that many of them involve the transition points in the implementation process. Although there are as many transitions points as there are steps (and subsets), some important ones often cause the most problems.

From Concept to Project Initiation

Many organizations find themselves stuck at the very beginning of the GIS development process. They have a notion that GIS would be good for them, but have trouble turning that concept into the required resources, which include a budget, staff time, a plan, approval to start GIS, and so forth. This often creates a chicken-or-egg problem: approval and funding to initiate a GIS project can be difficult to obtain without the project's proving its benefits, but you must have resources and time to do the work to establish the benefits.

Some strategies exist, however, to achieve this important transition. You may want to consider the following:

- *Demonstrate GIS.* Seeing the technology in action is often helpful to obtaining approval. Demonstrating the technology may involve getting management out to see a vendor or another organization's GIS. If you're using a vendor demonstration as an initiating tactic, however, it is better to conduct more than one demonstration. If management and users are given only one vendor's point of view, you may find yourself propelled straight into the acquisition phase.
- *Start Small.* Provide examples of GIS benefits using only small expenditures of resources. This can be done using existing resources such as software, data, and staff time.
- *Tie to An Immediate Operational Need.* If funds are needed to demonstrate any GIS benefits, they might be approved as part of a critical operational project that must be done anyway. For example, in the case of the Lawrence Livermore National Laboratory (LLNL) Plant Engineering (PE) organization, GIS is justified as a necessary technology for planning utilities or other projects.
- *Find an Executive-Level Champion.* Executive approval is usually required for obtaining the resources and mandate to proceed with GIS. Therefore, if someone at the executive level is a strong advocate of GIS, approval and resources may be granted much more quickly. Several GIS projects have moved ahead quickly with strong executive leadership.
- *Work Overtime.* Many GIS efforts have been successfully initiated only through the unpaid overtime of the GIS advocate. Once that person had demonstrated GIS benefits through work done "on the side," enough information was available for management to approve further GIS development. In some cases, you will find that no matter how much time is put into this effort, management is still against the project.

From Requirements Analysis to Design

Sometimes an organization can obtain a lot of information about its GIS requirements, but has difficulty transforming this information into a useful GIS design. Such problems arise from two sources. First, the information that was gathered may not be what is needed for design. This problem usually stems from the second, which is that the design goals were not fully understood before the requirements analysis was undertaken. Obviously, the requirements analysis should flow from the design objectives and approach, but there is a *potential pitfall* here.

An organization may be in hurry to do its requirements analysis (for any reason, although “just to do something” is the most common), or it may just follow the procedures, doing one step at a time, without fully understanding the whole process. To avoid these pitfalls, as mentioned above, the analysis of user requirements and the design steps are often bundled.

From Design to Acquisition and Development

This transition is a critical one in the GIS development process. Several different and concurrent routes can be taken at this point. Often, it is necessary to initially acquire and develop less than the full system design, which is acceptable and, in many cases, most practical. The trick to doing this correctly, however, is to complete the full system design to the extent that all pieces implemented in the short term will fit into the design in the long term.

The wrong way to implement short-term solutions is to short-circuit the design phase. Data, software, or hardware acquired or developed this way may not fit into the final system design.

Another important aspect of the transition into development is that many development activities must now take place concurrently: system specification and acquisition, organizational design, and planning and financial planning.

At this point, these two deviations from the “straight-line” development process—implementing only a portion of the GIS and concurrently developing different components—have proven difficult for many organizations. Until the design step, things are pretty simple. From this point on, the transitions are more complex to manage. The key is to remember that they are still straightforward, but there are more decisions to make and more things happening at one time; flexibility will be needed.

From Prototype to Final Design

A prototype can be a very useful tool for analyzing and designing a GIS. Prototypes help the designers communicate with the users about their requirements and how they want the system to perform. The major pitfall a prototype may present, however, is that once the users or managers see an “operational GIS” they may question the need to go through further system specification and selection. The viewpoint could apply to the data used in the prototype as well as to the system. The best way to avoid this bind is with appropriate education early in the process. Users and management need to understand the implications of GIS, the options available in the market, and the rationale behind the development and implementation process.

From Vendor Selection to Contract Initiation

Selecting a vendor or contractor for the GIS and data is frequently a long, intensive process that leaves the participants exhausted and well behind in their other duties. They are often relieved when it is over, but the problem is that the work has really only just begun at this point. There are a few key elements that need to be handled to allow the transition into contacting for the delivery of systems and data:

- *Contract Negotiation.* If the specifications in the request for proposals (RFP) is complete and the proposal was responsive, then contract negotiations are much easier. Items will always need to be loaned out and additions made before a contract can be signed, but these should only be clarifications to the proposal and the issues discussed in the selection process. Problems arise when the RFP is vague and, therefore, the proposals were not detailed enough. In this situation, a lot of work remains to be done at the contract-negotiation stage. Issues that were not adequately addressed in the selection process may actually become contract breakers. This situation basically boils down to pay now or pay later, that is, either invest your effort in a thorough specification and selection process, or extend your contract-negotiation time and resources.
- *Funding Allocation.* After a vendor has been selected, signing a contract means committing real money to the GIS; this is usually the first large expenditure. Some organizations get cold feet at this stage, particularly if the GIS commitment was weak to begin with, or if there was not full understanding of the cost vs. benefit implications. If this time is the first that the cost issue is really absorbed, the transition can become very difficult and can cause a project to stall.
- *Organization's Readiness.* Even if the funds are relaxed, the organization has many other things to do to prepare for the arrival of the GIS hardware/software, and/or data. The staff and procedures must be in place to deal with the setting up of the GIS. Equipment and data will be arriving, and the staff and procedures must be in place to deal with them. The process requires training, staffing, acceptance testing, quality control, data preparation, data maintenance, space, and time. Everyone has heard stories of GIS hardware/software that arrived and sat unused for months, or data that arrived and became useless because they were not checked or maintained. *The reality of the preparations that must be made for the arrival of GIS often stalls an organization's efforts.* But—it would be even worse to proceed with contract deliverables before these arrangements had been made.

From Pilot Project to Full Implementation

Some “successful” GISs that I have heard about never actually proceeded beyond the pilot project, which is understandable for a number of reasons. The two most common reasons are often the hardest to gain control over. They are funding and overuse of the pilot project.

Funding

Moving beyond the pilot project is often a problem. Some projects spend more than they had planned just getting to the pilot phase and then have trouble getting more

money. Some pilot projects are unconvincing and do not help justify more funding. Still other projects just have bad luck regarding the budgetary circumstances of the organization.

Overuse of the Pilot Project

Another major problem is overuse of the pilot project. If the organization does not have adequate GIS resources, it could spend all of those resources maintaining and extending the pilot rather than moving on with full implementation. User and management demands often drive this type of situation. If the pilot is successful and popular, this creates even more pressure from users to “do more of the same” rather than to move on with continued production of other data and applications. *Milestones and success measures for the project should be tied to the implementation of the full database and applications.* Do not allow satisfaction with the pilot project to take their place.

To avoid getting stuck in the pilot-project phase for either of these reasons, it is crucial to have a well-planned pilot project and a strong implementation plan for moving on to production, including the funding component.

From Development to Operation and Maintenance

Many aspects of a GIS effort change when the project moves from the development phase into the operation and maintenance phase. If any of these changes are not adequately planned and executed, the transition from development to operations could be very difficult. The following components must be adjusted to make this transition successful:

- *Goal and Approach.* In the development phase, the goal is to implement GIS to get the project done. A strong project management approach is required. After implementation, the focus shifts to operations and service. This step requires a different perspective and management approach, possibly including more of a service environment.
- *Performance Measurement.* As the goal and management approach shift, so do the measures of performance. In the development phase, project milestones could be mapped out and tracked as they are reached. In the operations phase, *performance is measured by how well the system is serving the needs of the user community.*
- *Financing.* As the GIS moves from the development to the operational phase, it may be appropriate to shift financial strategies. One type of financing may have been used to develop the GIS, much as the organization would develop any other facility. In the operational stage, the focus often shifts to financial operations and cost recovery.
- *Personnel.* Another important area of transition is often overlooked. As the GIS moves from development to operation, there will be shifts in personnel requirements and activities. This process is particularly important if much of the system development (i.e., applications or the data) was done in-house. What happens to excess people once the bulk of the work is done?

From Existing Organization to GIS Operation

Another important aspect of GIS transition involves the changes the organization must go through to successfully adopt GIS. A careful transition must be planned from the current operations, data flows, data usage, data dissemination, job tasks, and personnel responsibilities to those that are necessary with GIS operation. *Organization planning and change is a long and complex topic, but the important point to focus on is that this transition must be well planned and prepared for very early in the GIS process.* Organizational change takes a long time and is a good deal of work to accomplish, but the GIS will be misused, underused, or not used at all if this transition does not take place.

Plan and Manage the Transitions

Unless you count going backward, there are only two outcomes to the points between steps in the GIS implementation: stop or move forward. Most likely, you will somehow move forward, but how smoothly and quickly you do so depends on how well you plan and manage these important transitions.

Bibliography

Autenucci, J., et al. *Geographic Information Systems: A Guide to the Technology*. Van Nostrand Reinhold: 1991.

Although any book addressing technology naturally becomes dated, the process-oriented sections of this book remain very applicable. The process is well explained; however, it generally assumes an environment involving many users and relatively large budgets.

Huxhold, W., and A. Levinsohn. *Managing Geographic Information System Projects*. Oxford University Press: 1955.

This book is particularly oriented toward the planning stages of a GIS project. This approach leaves some holes in the discussion of other parts of the implementation process, but the whole process is at least outlined. This book also assumes a large, multi-participant, public-sector GIS project.

Maguire, D., et al., editors. *Geographic Information Systems: Principles and Applications*. Longman Scientific & Technical: 1991.

This two-volume publication has chapters addressing most aspects of GIS, and the implementation process comprises one chapter.

Montgomery, G., and H. Schuch. *GIS Data Conversion Handbook*. GIS World, Inc. and UGC Consulting: 1993.

This book covers the data conversion parts of the GIS implementation process, providing a nice supplement to those sources that gloss over this step.

Somers, R. *GIS Implementation and GIS Management Issues Workbooks*. Rebecca Somers: 1995.

These workbooks only provide outlines for the process and issues related to GIS implementation, as they are meant to accompany instruction.

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